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Technical note

A method for the calibration of concave $^{90}Sr+^{90}Y$ ophthalmic applicators

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1. Introduction

In the United States of America, most ophthalmic applicators are of the planar type and consist of $^{90}Sr+^{90}Y$ (maximum energy about 1.8 MeV and average energy about 0.8 MeV on the outside of the encapsulation) (Pruitt *et al* 1988). There do exist, however, some which are concave in shape. An example is the Amersham Model SIA.6, which has a radius of curvature of 10 mm. (The identification of commercial products is solely for technical purposes and does not imply endorsement by the National Institute of Standards and Technology, USA.) Curved applicators are commonly used throughout Europe, though in that case they seem to be mostly $^{106}Ru+^{106}Rh$ (maximum energy 3.5 MeV, average energy 1.5 MeV) and are used to treat more deep-seated lesions. In recent years there have been papers dealing with the calibration of such concave applicators, using thermoluminescence dosimeters (TLD) (Binder *et al* 1990), alanine-polymer foils (Hjortenberg *et al* 1989) and silicon detectors (Lax 1991). There have also been calculational attempts to predict depth–dose characteristics from measurements with extrapolation chambers at distances of several millimetres from the source surface (Davelaar *et al* 1991).

At the Amersham Laboratory (Amersham, UK) absorbed-dose rate in tissue at a depth of 7 mg cm^{-2} from curved applicators is measured with calibrated scintillator probes (Amersham International 1979, Sinclair and Trott 1956). The probes are approximately 3 mm in diameter, 0.5 mm thick and are covered with 7 mg cm^{-2} of aluminium. They are calibrated using standard sources whose dose rate has been determined using an extrapolation chamber equipped with a 3 mm diameter collecting electrode. Crucial to this technique is the availability of well calibrated sources of nearly the same geometry and dose rate as the source to be calibrated.

None of the above methods adequately addresses the question of measurement of surface absorbed-dose rate from a concave applicator. A technique is presented here which yields accurate measurement of the surface absorbed-dose rate in a very simple and straightforward fashion.

2. Experimental method

Absorbed-dose rate at the source surface averaged over the central 4 mm diameter area was determined from measurements with calibrated radiochromic foils

Table 1. Comparison of calibration results.

Source	Measured dose rate Gy s^{-1}		
	Radiochromic foil	Scintillator probe	% Diff
0116ML	0.28	0.26	8
1181	0.040	0.034	18

(GafChromic™) (Saylor *et al* 1988, McLaughlin *et al* 1991). The foils consist of a 6 to 8 μm thick sensitive emulsion coated on to a 100 μm thick polyamide base. The film batch is calibrated using a well standardized ^{60}Co gamma-ray field over an absorbed dose range from 50 to 1000 Gy.

For the two sources studied, seven 5 mm diameter foils were exposed to each source, each foil sandwiched between the concave source surfaces and a 19 mm diameter polystyrene sphere. The doses delivered to the foils were between 200 and 600 Gy depending upon source strength. During irradiation, the curved source was held rigidly in place using a clamp and a ring stand. The small size of the foil disc allows a good contact with both the source and the sphere surface. In conjunction with these irradiations, six other foils were exposed to a ^{90}Sr+^{90}Y planar source, which had been calibrated using an extrapolation ionization chamber as described elsewhere (Soares 1991). Since the film responds nearly equally (to within ±5%) to ^{60}Co gamma rays and ^{90}Sr+^{90}Y beta particles (Soares 1991) this additional step should not be necessary. However, due to variations in the thickness of the sensitive emulsion layer, the exposure of foil samples (cut from areas adjacent to those used for the unknown source exposures) to the known beta-particle source serves to correct the responses of foils exposed to the unknown source for variations both of emulsion thickness and radiation quality. Hence, the overall accuracy and precision of the measurement is improved.

The foils were read with a scanning laser densitometer and the resulting array of densities converted to absorbed dose to water using the calibration curve. These dose interpretations were then averaged over the central 4 mm diameter of the films to yield average absorbed dose rate. The final dose rate determination was made by correcting the dose interpretations of the foils irradiated by the unknown source by using the dose interpretations and measured absorbed-dose rate of the known source. For the two sources calibrated in this way, this correction amounted to less than 2%.

3. Results

The absorbed-dose rates to water at the surface of the source as determined from the radiochromic foil measurement are given in table 1 in SI units (Gy s^{-1}). This rate is considered to be an average of the dose rate across the central area of the source surface. The overall uncertainty in the calibration is estimated to be ±15%, the components of which are detailed in table 2. The random uncertainty components are calculated as standard deviations of the mean of replicate readings; the uncertainty in the NIST planar source calibration is described elsewhere (Soares 1991). The overall uncertainty is twice the square root of the quadratic sum of all the component uncertainties; it is considered to have the approximate significance of a 95% confidence limit.

Table 2. Estimated uncertainties in source calibration using radiochromic films.

Component	Uncertainty (%)
Calibration of NIST standard source	6
Response of standard source calibration films	3
Response of films exposed to source under test	3
Combined uncertainty (quadratic sum)	7.5
Overall uncertainty (combined ×2)	15

The dose rates measured for the two sources are compared to values determined at Amersham International using a calibrated scintillator probe in table 1. The average difference between the two methods is about 10%, which is consistent with the current difference between this laboratory and the Amersham International Laboratory (Soares 1991). Given the quoted uncertainty of this measurement (±15%) and that quoted by Amersham International for measurements on concave applicators (±30%) (Amersham International 1979), the agreement is satisfactory. In the future it is hoped that these measurements can be extended to $^{106}Ru+^{106}Rh$ ophthalmic applicators in order to compare with other calibration methods. Given the relative ease with which the dye–foil measurements can be made, the technique is an attractive alternative to more conventional methods such as TLD or solid state probes.

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